utilizes specially developed field techniques and signal-intensifying processes. The method has since been fully demonstrated and evaluated, and in many of the more difficult exploration areas of the United States and Canada it has proved to be an advanced tool for petroleum exploration. Advanced digital seismic data-processing centres have been established in New Orleans, Louisiana, and Midland, Texas, to augment the Dallas centre and to meet increased demands. A fourth centre began operation during January 1965 in Calgary, Alberta, and a fifth is to be opened shortly in London, England. A seismic detection system for perimeter defence in jungle warfare has been delivered to the U.S. Marine Corps, and a scheme for geophysical experiments to be carried out on the surface of the Moon under the *Apollo* programme has been prepared. Mr. E. McDermott, who was co-developer of the seismic reflexion technology which has been applied universally in exploration for petroleum and other mineral deposits, and who was co-founder in 1930 of Texas Instruments' predecessor company, Geophysical Service, retired as chairman of the executive committee of Texas Instruments, Inc., on December 31, 1964, and Mr. Haggerty, president and chief executive officer, has assumed also the office vacated by Mr. McDermott.

THIN FILM RESEARCH

THE twelfth meeting of the Thin Films Group (formerly the Dielectrics Evaporation Group) was held at Harlow during March 24–25. The Research Laboratories of Associated Electrical Industries and Standard Telecommunication Laboratories, Ltd., acted as joint hosts, and visits were made to both of these. The following papers were read: "Ellipsometry", by Mr. B. H. Clausen (Standard Telecommunication Laboratories, Ltd., Harlow); "Defects in Evaporated Silicon Films", by Mr. D. J. Thomas (Standard Telecommunication Laboratories, Ltd., Harlow); "Nucleation Studies on Freshly Cleaved Crystalline Surfaces", by Mr. D. Stirland (Alan Clark Research Centre, Caswell); "Nucleation and Charge on Glass Substrates", by Dr. R. Hill (Electrical Research Association, Leatherhead); "Lorentz Electron Microscopy: Magnetic Imaging in the Electron Microscope", by Mr. A. Green (International Computers and Tabulators, Stevenage); "Oxidation in a Glow Discharge to Prepare Dielectric Films", by Mr. D. White (Associated Electrical Industries, Research Laboratories, Harlow); "Conduction Processes in Dielectric Films", by Mr. J. Simmons (Standard Telecommunication Laboratories, Ltd., Harlow); "Some Readily Evaporated Semiconducting Compounds", by Dr. J. Zemel (Imperial College of Science and Technology—read by Mr. Juhasz, also of Imperial College); "Initial Stresses in Evaporated Films", by Mr. P. Carpenter (Alan Clark Research Centre, Caswell) and Mr. J. D. Wilcock (Imperial College of Science and Technology).

The theme of this meeting was the study of surfaces with special reference to the early stages of growth in thin films. Perhaps the most interesting new results presented were those of Stirland and Hill, whose papers were to a large extent complementary. In the hope of finding a reproducible surface, which is the dream of every electron microscopist, Stirland has cleaved single rock salt crystals *in vacuo* and evaporated gold from the same source on to the two faces produced. Topographically, one should be a mirror image of the other apart from damage produced in cleaving. He has used a combination of optical microscopy and numbered specimen grids to locate the equivalent areas on the two faces for electron microscopy. Results showed excellent correspondence of cleavage step and dislocation decoration, but no exact correlation of nucleation site position along the cleavage steps or on the flat areas in between. Exposure of one of the crystal faces to moist air before deposition showed considerable effects on the decoration pattern produced.

Hill has examined the effects on film structure both of electrons incident from the source and of the application of a d.c. field across the growing film. His micrographs show that both processes can affect the type of nucleation and growth and the number of nucleation sites available. His work was done with gold on glass substrates at pressures of 10^{-8} mm mercury or better. The use of Hill's technique to prevent stray electrons from the source striking the substrate might perhaps affect some of Stirland's results on nucleation site correspondence. In order to detect the presence of surface charges on the substrate prior to deposition, a potential probe was applied. This gave, in fact, a very sensitive indication of the beginning of nucleation.

The paper on ellipsometry described a technique which is somewhat unfamiliar to many. Using a collimated beam of elliptically polarized light reflected from the specimen surface, the growth of a thin film can be followed *in situ* by observing changes in the optical constants. The method can be applied to films immersed in liquids and hence is well suited to investigations of anodic film growth and of corrosion or adsorption processes. Owing to the number of variables involved it is necessary to use computer techniques to obtain calculated curves to which the experimental results are fitted as well as possible.

Lorentz electron microscopy is a highly specialized method for examining the magnetic structure of very thin films. A stream of electrons passing near a region of magnetic inhomogeneity is deflected in such a way as to cause an intensity distribution on the screen which corresponds to the variation in the magnetic structure of the film. This method can reveal not only domain walls but also the fine magnetic structure within the domains, and such applications were described in detail by Green.

Electron microscopy has been applied to the study of stacking faults in 'epitaxially' grown silicon deposited by evaporation and by vapour deposition. The incidence of such faults is greatly increased by the presence of silicon carbide formed from pump oils. It is interesting to see that, according to the workers at the Standard Telecommunication Laboratories, Ltd., the use of a gold silicon alloy to promote epitaxy (see Nielson, S., *Nature*, **205**, 755; 1965) increases the liability to form faults in the deposit due to thermal strain.

The difficulty of depositing silicon throws into high relief the ease with which single crystal films of lead sulphide, telluride and selenide (and perhaps of related compounds) can be deposited by evaporation. Measurements on the electrical and optical properties of these materials by Zemel, and, in particular, of the electronic mobilities, show that the values obtained approach those of bulk single crystals. (Thus, lead telluride shows a bulk value of 30,000 and a value of 23,000 has been obtained for the film at 77° K.) Juhasz has examined these films by electron diffraction and was able to show an almost perfect Laue diffraction pattern. Since epitaxy was observed even with lattice-misfit greater than 50 per cent it seems that, for these materials at least, substrate surface state is by far more important than lattice correspondence. This was confirmed by Pashley during the ensuing discussion. Juhasz concluded with a graceful compliment to the pioneering work of Wilman, who demonstrated the epitaxy of these compounds as early as 1938.

The relation between details of films structure as revealed by electron microscopy and the mechanical and

electrical properties of the films is an essential link in any comprehensive investigation of film growth. Carpenter and Wilcock (both of whom are working under the direction of Mr. D. Campbell, one in a university, the other in a commercial laboratory) are using very sensitive measuring equipment for the study of initial stresses in thin films of a type on which structural data are available. They are at present seeking to relate the onset of visible nucleation with the first appearance of stress.

White has investigated the preparation of thin insulating films by 'field-assisted anodization' or 'biased sputtering'. Results so far do not fully confirm claims made by some workers in the United States that the process is comparable with aqueous anodization. It appears to differ not only in its low-current efficiency but also in the properties of the films prepared, and the independence of their thickness of applied bias voltage.

J. R. Balmer
J. H. Bruce

MECHANISM OF CELLULASE ACTION

A ONE-DAY symposium on the mechanism of cellulase action, under the auspices of the Molecular Enzymology Group of the Biochemical Society, was organized by the Shirley Institute on May 28, 1965. Dr. J. Honeyman, who presided, commented that Mr. Selby took this opportunity to arrange a symposium because both Dr. Elwyn T. Reese, from Natick, Massachusetts, and Dr. Bruce A. Stone, from the University of Melbourne, were at present working in the United Kingdom. The Shirley Institute had for several years been active in cellulase research, particularly in work designed to elucidate the mechanism of the biodeterioration of cotton.

K. Selby (Shirley Institute) gave the first paper on the enzymatic degradation of cotton. He stressed that since many 'cellulases' classified by Reese as C_x can attack soluble cellulose derivatives or swollen cellulose but not native celluloses, the structure of the solid cellulose must govern its susceptibility to attack; if we knew more about the structure we would understand the enzymes better, and vice versa. Although opinion is now tending towards the belief that cotton is entirely composed of crystalline microfibrils without amorphous regions, there exist inhomogeneities in the structure, ranging in size from interfibrillar holes to the layer-structure of the cotton hair, and these may provide sites for enzymatic attack. If cotton could be chemically modified in these accessible regions it might be protected against attack, and this has been done with some success by Mr. Colbran at the Institute by reaction with phenyl isocyanate under non-swelling conditions. Work on the cellulase system of *Myrothecium verrucaria* was reported; exclusion chromatography separated a C_x from two other components both capable of weakening cotton, and both, like the activity of the crude filtrate, 'exhausted' in the process. The cellulase of *Trichoderma viride* does not suffer from this disability and seems to be a better agent for examining cellulose structure.

In subsequent discussion, J. O. Warwicker (Shirley Institute) made it clear that it is still possible to explain the physical and chemical properties of cotton which had previously been attributed to the amorphous part of its structure.

B. A. Stone (University of Melbourne) then gave an account of his work on the purification of the exo-β-1,4-glucanase (cellulase) of *Aspergillus niger* and its action on glucans with mixed 1,4- and 1,3-linkages. Elution chromatography removed cellobiase (probably an exo-β-1,4-glucanase) and endo-β-1,3-glucanase (laminarinase) and the resulting cellulase digested carboxymethylcellulose with a fall in viscosity that demonstrated its chain-cleaving action. Barley glucan was broken down by this cellulase to give some glucose, cellobiose and mixed-link tri- and tetra-saccharides both with 1,4-linkages at the reducing ends. This result confirms that of Perlin and Reese with *Streptomyces* cellulase and should be interpreted in the same way. However, Stone found that the cellulase still contained exo-β-1,3-glucanase and that after removing this by adsorption on insoluble laminarin the products of digestion of barley glucan were significantly changed. Glucose was practically absent, but there were present, as stable products, about 20 per cent of pentasaccharides and higher sugars which, so far as their structures had been determined, all showed the cellobiose grouping at the reducing end. This purified cellulase should be a powerful tool in the investigation of mixed-link glucans.

E. T. Reese (Quartermaster Research and Engineering Center, Natick, Massachusetts) reviewed work on β-glucanases, leaving a vivid impression of the multitude and variety of these enzymes and the complexity of their specificity. In particular, the work of Perlin showed that several endo-glucanases are not specific to the bond being broken but to the nature of the reducing end-unit being liberated. A surprising example of this is that, acting on a glucan with alternate 1,3- and 1,4-linkages, cellulase, producing cellobiose, would attack the 1,3-linkages, and laminarinase, producing laminaribiose, would attack the 1,4-linkages. How far this is true of all endo-glucanases is not clear. The growing class of known exo-glucanases act from the non-reducing end of the glucan; many of them liberate disaccharide molecules, and some have been shown to attack more than one kind of bond. Some exo-glucanases are blocked in their endwise action by substituent groups and branches in the glucan, but a case was given of an exo-1,3-glucanase, from a basidiomycete, which is not stopped by 1,6-branchpoints in a 1,3-glucan.

C. C. Maitland (Shirley Institute) described present work on the cellulase of *Trichoderma viride* and its attack on cotton, which it is able to solubilize entirely. Exclusion chromatography on 'Sephadex' *G*-75 separates the system into three major components. One component, of low molecular weight, accounts for the greater part of the activity against carboxymethylcellulose but plays no recognizable part in the solubilization of cotton. The two other components are probably identifiable with Reese's C_x and C_1, the C_x having activity against carboxymethylcellulose and cellobiose, while C_1 has little or no such activity but acts synergistically with C_x in solubilizing cotton. The nature of this synergism, first found by Reese and co-workers but now shown more markedly than before, was discussed. The implied division of labour could be based on the structure of the cotton hair, but this seems unlikely because acid degradation and ballmilling, although destroying the large-scale structure of cotton, do not entirely remove the synergistic effect. It is generally assumed that C_1 initiates the attack on cotton and C_x follows; this is very likely, but there is no direct evidence for it. However, the small solubilizing power of C_1 acting alone is enhanced when the incubation with cotton takes place on a dialysis membrane; this indicates that an inhibitory product of C_1 action, which C_x would presumably have removed, is now able to diffuse away.

G. Halliwell (University of Strathclyde) then spoke of his work on cellulases at the Rowett Institute. Rumen bacteria, although capable of extensive breakdown of solid cellulose, do not yield powerfully cellulolytic filtrates, but *Trichoderma* species do both, and the breakdown of fibrous cellulose (cotton) was investigated by using their filtrates. Of particular interest was the observation that an early stage of attack, noticeable by the breakdown of the cotton into insoluble fragments, of which the smallest were capable of passing through a